SCIENCE FOR CERAMIC PRODUCTION

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BASALT TUFF CERAMICS

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Results of physicochemical and technological studies of basalt tuff as a new type of raw material for construction ceramics are considered. Tests carried out under production conditions corroborated the expediency of using basalt tuff in production of building bricks, roof tiles, and facade tiles.

Among relatively little studied ceramic materials are pyroclastic (volcanogenic-detrital) rocks that contain, in addition to fragments of the initial effusive rocks, products of their disintegration. A typical representative of such rocks is basalt tuff, which is often bedded together with basalt, and in spite of its substantial resources in the Rovno Region (Ukraine), which has the largest basalt tuff deposits in Europe, this material has not been used extensively so far.

Basalt tuff is a stony rock with a true density of 2640 – 2720 kg/m^3, an average density of 1700 – 1820 kg/m^3, and a compressive strength of 5 – 15 MPa. Its water absorption is 11 – 14% (weight) or 19 – 27% (volume), and its swelling in water is 15 – 36% in the powdered state and 42 – 62% in the presence of $CaCl_2$ coagulant.

Basalt tuff has a porphyry structure. The chemical composition of basalt tuff from Rovno Region deposits is within the following limits (wt.%): 8 – 10 CaO, 3 – 5 MgO, 12 – 15 Al_2O_3, 11 – 14 (Fe_2O_3 + FeO), 2 – 4 (Na_2O + K_2O), 49 – 51 SiO_2, 2 – 3 TiO_2, 3 – 5 calcination loss. On the diagram of A. I. Avgustinik (Fig. 1), basalt tuff is adjacent to typical brick clays in chemical composition and differs from the latter by a somewhat higher content of iron oxides and an increased molar ratio Al_2O_3 : SiO_2 with a maximum permissible total content of basic oxides and iron oxides.

The phase composition of the basalt tuff is represented by plagioclase (30 – 40%), pyroxene (10 – 20%), magnetite (6 – 9%), hydrated minerals (up to 20%), and recrystallized glass (5 – 10%). An x-ray phase analysis identified mainly labrador in the plagioclase group, diopside and augite in the pyroxene group, and olivine in the olivine group. Hydrated aluminosilicate minerals in the basalt tuff are represented by gmelinite (a mineral of the zeolite group), argillaceous minerals are represented by chlorite, illite and glauconite are present from the hydromica group, and beidellite is present from the montmorillonite group. Just like ordinary clay material, basalt tuff contains silica inclusions in the form of β-quartz. The presence of magnetite is established.

The basalt tuff was subjected to sedimentation analysis after milling in a ball mill and sifting through a No. 008 sieve. It was found that the content of particles below 10 μm in the tuff is 60 – 65%, whereas in typical loess-like loam this content does not exceed 35%.

The content of clay materials in the tuff determined in accordance with B. I. Rutkovskii's method based on the capacity of clay particles for swelling in water is around 17%. In V. V. Okhotin's diagram, based on the proportion of argillaceous, powdered, and sand fractions, the basalt tuff belongs to the loam region after grinding in a ball mill to a residue of 5 – 10% on a No. 008 sieve. The polydisperse material contains 17.2% argillaceous material, 50% sand, and 32.8% powdered fraction. The bulk density of the milled tuff is within the limits (0.97 – 1.22) × 10^3 kg/m^3, and the specific surface is 130 – 150 m^2/kg.

The plasticity number of the tuff was determined for three fractions according to A. N. Vasil'ev's method: 1.00 – 0.63 mm, 0.63 – 0.25 mm, and below 25 mm. The plasticity number was, respectively, 5.6, 6.2, and 7.4, which corresponds to a low-plasticity material. The molding moisture of a tuff mixture of normal consistency was determined employing a Vicat device. As the fraction size decreases, the moisture content increases from 19.5 to 25.0%. The drying sensitivity coefficient of the samples (according to A. F. Chizhskii) varies from 1.04 to 1.70, which correlates with the medium-sensitivity grade of clays, and the air shrinkage is within the limits of 3.3 to 5.5%.

When plastically molded samples of milled basalt tuff are fired within the temperature interval of 950 – 1100°C, their water absorption decreases from 17 – 18 to 6 – 9%, and the fire shrinkage increases from 3 – 5 to 6 – 8%. Here, lower water absorption values and higher fire shrinkage va-

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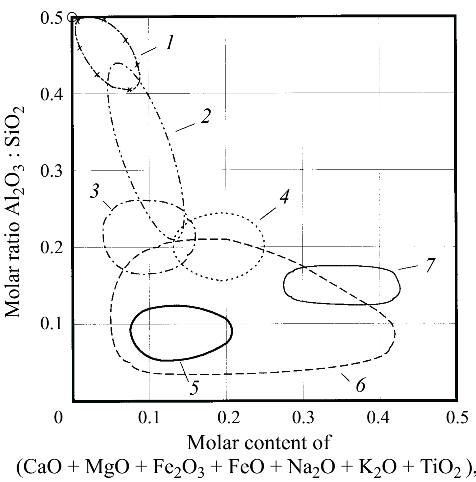

Fig. 1. Classification based on chemical composition for clays used in production of: *1*) refractory chamotte; *2*) floor tiles, sewage-pipe tiles; *3*) pottery and terracotta; *4*) roof tile; *5*) bridge clinker; *6*) brick; *7*) basalt tuff.

lues are characteristic of samples of tuff powder with a particle size below 0.25 mm. At a temperature over 1100°C, the samples exhibit signs of overburning, and at 1150 – 1200°C they melt.

To determine the effect of the granular composition of the initial powder on the strength of basalt tuff ceramics, a two-factor three-level experiment design was implemented. Ratios of the fraction volumes V_1, V_2, and V_3 were varied by varying the factors x_1 and x_2, V_1 for $d_1 < 0.08$ mm, V_2 for $d_2 = 0.08 - 0.20$ mm, and V_3 for $d_3 = 0.20 - 1.00$ mm, where d_1, d_2, and d_3 are the sizes of the basalt tuff particles, and $x_1 = (X_1 - 0.5)/0.5$ and $x_2 = (X_2 - 0.5)/0.5$, where $X_1 = V_1/(V_1 + V_2)$ and $X_2 = (V_1 + V_2)/(V_1 + V_2 + V_3)$.

The regression equation that adequately describes the effect of the factors X_1 and X_2 (in coded variables) on the strength of samples fired at a temperature of 1000°C is as follows:

$$y = 24.2 + 1.38x_1 + 5.7x_2 - 0.83x_1^2 - 3.23x_2^2 + 1.2x_1x_2. \quad (1)$$

Using the above equation, it is easy to calculate the fractional composition of mixtures that provide the required strength. Since the sum of the volumes of the three fractions has to be equal to unity, $V_1 = X_1X_2$, $V_2 = (1 - X_1)X_2$, $V_3 = 1 - X_2$. An isoparametric analysis of Eq. (1) performed on the concentration triangle (Fig. 2) shows that with respect to the strength of the ceramics, compositions in which the finest fraction and relatively coarse fraction prevail are preferable. The first fraction presumably acts as a binder and the second as a filling agent.

The properties of basalt tuff ceramics and the technological regimes for its production can be modified by introducing additional argillaceous components and burning-out and other additives.

The effect of factors that take into account the ratio of the absolute volumes of low-melting loam V_{lm} and tuff V_t

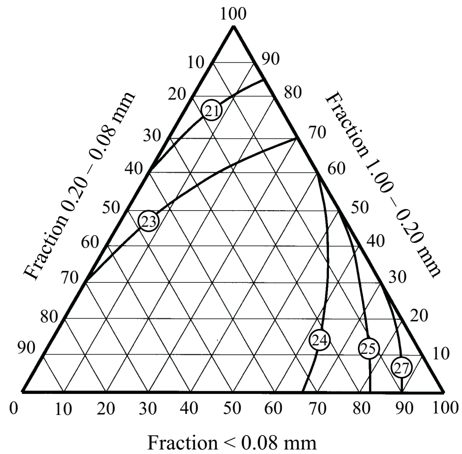

Fig. 2. Concentration triangle of the fractional composition of the mixture with strength isolines of basalt tuff ceramics (in MPa).

($X_1 = V_{lm}/V_t$) and the amount (above 100%) of carbon-bearing waste ($X_2 = V_{CBW}$) was investigated.

The experimental-statistical model of the strength of a ceramic material made by plastic molding and fired at 950°C is as follows:

$$y_1 = 12.23 + 1.33x_1 - 1.62x_2 + 0.22x_1^2 - 1.76x_2^2 + 0.95x_1x_2, \quad (2)$$

where $x_1 = (X_1 - 1.5)/1.5$; $x_2 = (X_2 - 0.075)/0.075$.

It follows from model (2) that the strength of basalt tuff ceramics without additives of loam and carbon-bearing waste (CBW) after firing at 950°C is relatively low, as could be expected (5.7 MPa). A low-melting loam additive increases the strength of basalt tuff ceramics. In particular, introduction of 7% CBW into the mixture in addition to the tuff facilitates uniform sintering of ceramic crock, increases its porosity, decreases its heat conductance, and decreases the sintering temperature. Here, the strength of the ceramics after firing at 950°C is 13 MPa.

As a result of tests carried out at the Rovno Construction Materials Works, it was established that introduction of low-melting loess-like loam in the form of powder (up to 30%) into basalt tuff in the presence of a burning-out additive of CBW makes it possible to improve the molding conditions and increase the grade strength of brick by 1 – 2 grades.

Laboratory and industrial tests demonstrated the possibility off using basalt tuff as the main material in production of ordinary and facing brick, roof tile, and facade tile employing plastic, rigid, and dry-press molding. The products have a saturated terracotta color, and their properties meet current standards [1].

Use of basalt tuff expands the available natural resources for ceramic construction materials and contributes to integrated use of mineral material.

REFERENCES

1. L. I. Dvorkin and I. G. Skrypnik, “Pyroclastic rocks as a new type of ceramic raw material,” in: *Int. Sci.-Tech. Conf. “Development of Engineering Chemistry in Ukraine,” Issue 1* [in Russian], Kharkov (1995), pp. 214 – 215.